MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

MODULE 210002, 2015/2016

EPH7236 – SOLID STATE LIGHTING

(All sections / Groups)

4 JUNE 2016
2:30 p.m. – 5:30 p.m.
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **All** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) What are the advantages of solid-state lighting that will potentially lead to the value added services in the near future? [4 marks]

(b) Make a comparison between LED lighting and incandescence lamp lighting in at least five aspects. [5 marks]

(c) Solid state lighting will dominate convention lighting even though solid-state lighting has higher initial fixture cost. Considering the operating time justify the above statement with relevant cost analysis diagram. [3 marks]

(d) Solid angle concept is used to measure the portion of space into which a point source is radiating. In the context of the previous statement what is 'Solid Angle (Steradians)'? [5 marks]

(e) Explain with relevant diagram of possible measurement geometry for any **TWO** mode of spectroradiometer from the list below:

(i) Irradiance mode spectroradiometer
(ii) Total flux mode spectroradiometer
(iii) Partial flux mode spectroradiometer

[8 marks]

Continued ...

Question 2

(a) Semiconductor LED chips are commonly encapsulated by an optically transparent encapsulant. Assume that the refractive index of an encapsulant is $n_1 = 1.6$. The Fresnel reflection at the encapsulant-air boundary can be calculated as:

$$R = \left(\frac{n_1 - n_{air}}{n_1 + n_{air}}\right)^2 = \left(\frac{\Delta n}{n_1 + n_{air}}\right)^2 \propto \Delta n^2$$

i) What is the reason that an encapsulant is being used in LEDs? [1 mark]

ii) Calculate the Fresnel reflection at the encapsulant-air boundary. [2 marks]

iii) To reduce the Fresnel reflection at the encapsulant-air boundary, one can employ a second encapsulant forming a thin layer on the first encapsulant. The second encapsulant has a refractive index of n_2. Sketch the device having two encapsulatants. [1 mark]

iv) Assume that the reflectivity at the two interfaces (i.e. encapsulant-2 and encapsulant-2-to-air) add up ($R = R_1 + R_2$). Give a formula for the total reflectance as a function of n_2. [4 marks]

v) Show that n_2 has an optimum value, that is, a value at which the Fresnel reflection is minimized. [3 marks]

(b) In an LED display, three different light-emitters are used, emitting monochromatically in the red (620 nm), green (520 nm), and blue (450 nm). Each of them consists of a UV LED (400 nm) and a phosphor. Assume that the external quantum efficiency for each of the three light-emitters (UV LED + phosphor) is 20%.

i) Under a forward current of 500 mA (LEDs are in a series circuit), what is the number of photons emitted per second from each of the three light-emitters (UV LED + phosphor)? [2 marks]

ii) What is the optical power emitted from each of the three light-emitters? [3 marks]

iii) Given the above discussion, what could be the energy loss mechanisms in these light emitters? [1 mark]

iv) Light-emitters usually have a spectral broadening. Consider the locations of the three lightemitters in the chromaticity diagram, which chromaticity location (red, green, or blue?) will move more towards the center of the diagram upon spectral broadening, and why? [1 mark]

v) Which chromaticity location (red, green, or blue?) will be affected least upon spectral broadening, and why? [1 mark]

vi) What is the effect of spectral broadening of the light-emitters to the range of colors (area of color gamut) that can be created from combinations of the three light-emitters? [1 mark]

vii) Give an example as to what kind of color is lost (no longer displayable) because of the spectral broadening of the three light-emitters? [1 mark]

(c) What are the advantages of high power packaged LED over that of low power packaged, briefly explain with relevant diagram. [4 marks]

Continued ...

Question 3

(a) Briefly explain Injection Luminescence in the radiative recombination process where does radiative recombination occurs. [3 marks]

(b) With the aid of an energy band diagram, explain Double heterojunction (DH) LED structure. How it is differed from single hetrojunction LED structure. [8 marks]

(c) Draw the structure of (i) A double heterostructure diode (ii) its unbiased energy level diagram (iii) Forward biased energy level diagram and explain the principle of operation. [8 marks]

(d) Under high injection currents, i.e. high injected carriers, all the states available in the Quantam Well LED can be occupied by electrons. This will saturate the optical power. Describe how multiple quantum well LED can overcome this. [6 marks]

Continued ...

Question 4

(a) Explain with diagrams the different possible top-contact geometrics for high-brightness LEDS. [2 marks]

(b) Explain the current-voltage characteristics of different types of high-brightness LEDs depicted by the Figure Q4 (b) below.

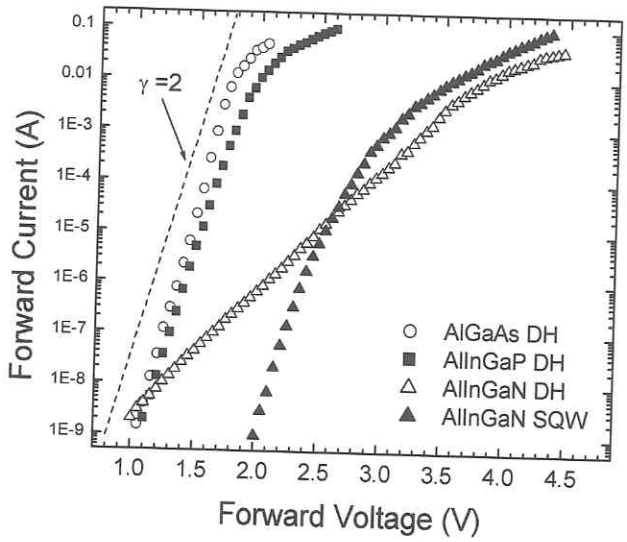

Figure Q4 (b)

[6 marks]

(c) What are the types of current controls to operate LEDs? What are their advantage(s)?

[3 marks]

(d) Explain with relevant diagram the use of spherical chip to make all the emitted photons arrive at the semiconductor surface within the critical angle.

[6 marks]

(e) Describe how a dichromatic phosphor conversion LEDs is used to produce white lights.

[8 marks]

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